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Performance Correlates of
Social Behavior and Organization of Non-Human Primates

Annual Report

July 1978

(1 April 1977 - 31 July 1978)

Bradford N. Bunnell

Joseph D. Allen

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701

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Department of Psychology
University of Georgia
Athens, Georgia 30602

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The purpose of this report is to identify and investigate performance variables that are correlated with social rank, social behavior, and social organization in monkeys of the genus Macaca. Java males from three troops (T-troop, NT-troop and I-troop, recently formed with males selected from T- and NT-troops) were assigned to two or more of the following behavioral tests: (1) VI-frustration task, (2) change-over ratio task, (3) various complex problem solving tasks, and (4) open field tests. (over)

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Results from the current year's work have largely confirmed and extended previous findings of relationships between social variables and learning performance in the laboratory. In adult males, there is a tendency for poor performance to be associated with high rank both on complex learning tasks and on various operant schedules where response bursting is associated with high rank or frequency of aggressive responses. New data indicate that higher ranking animals enter a strange environment more readily than lower ranking animals. Also new is the apparent better performance of higher ranking males on acquisition of a changeover ratio schedule. This, if it holds up as testing continues over the next few months, will be the second instance of better performance by high ranking animals that we have obtained. In previous work, acquisition of efficient performance on a DRL schedule was positively correlated with high rank. Finally, the use of new techniques for assessing the social structure, organization, and dynamics of our social groups is expected to provide the basis for a much clearer understanding of the dimensions which account for the social/performance relationships that have, and are, emerging.

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TABLE OF CONTENTS

Summary, Abstract, or Digest

The purpose of this report is to identify and investigate performance variables that are correlated with social rank, social behavior, and social organization in monkeys of the genus Macaca. Java males from three troops (T-troop, NT troops and I troop, recently formed with males selected from T and NT troops) were assigned to two or more of the following behavioral tests: 1) VI-frustration task, 2) change-over ratio task, 3) various complex problem solving tasks, and 4) open field tests.

Results from the current year's work have largely confirmed and extended previous findings of relationships between social variables and learning and performance in the laboratory. In adult males, there is a tendency for poor performance to be associated with high rank both on complex learning tasks and on various operant schedules where response bursting is associated with high rank or frequency of aggressive responses. New data indicate that higher ranking animals enter a strange environment more readily than lower ranking animals. Also new is the apparent better performance of higher ranking males on acquisition of a changeover ratio schedule. This, if it holds up as testing continues over the next few months, will be the second instance of better performance by high ranking animals that we have obtained. In previous work, acquisition of efficient performance on a DRL schedule was positively correlated with high rank. Finally, the use of new techniques for assessing the social structure, organization, and dynamics of our social groups is expected to provide the basis for a much clearer understanding of the dimensions which account for the social/performance relationships that have, and are emerging.

Forward

In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Facilities and Care" as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences-National Research Council.

Body of the Report

A. Social Behavior and Organization:

(1) Group composition.

Until April, 1978, there were two groups of Java monkeys (*M. fascicularis*) under observation. The composition of these two groups was described in our last annual report (Bunnell and Allen, 1977). Because of unexpectedly high mortality among females over the past three years, the age-sex ratios in the groups had shifted so that the composition of the groups no longer approximated that described for groups found in the wild (Angst, 1975). There was disproportionately large numbers of adult males and too few females of all ages. In April, 1978, we began to restructure our groups in an attempt to partially restore the appropriate age-sex ratios. Five adult males

were removed from one group, "T-Troop", and four from the other, "NT-Troop". These animals were individually housed in the laboratory until the middle of May, when we began to put them together to form a third group "I-Troop". This all male group was formed by introducing seven males to each other simultaneously and observing their social behavior over the succeeding two weeks. At this time, the eighth animal was added; the ninth will be introduced on June 13, 1978. T- and NT-Troops are being further restructured by switching one high ranking male from each troop to the other troop. These animals were removed from their original troops at the same time as the I-Troop males. "Knees", who had ranked second in NT-Troop when removed, is scheduled to be introduced into T-Troop during the week of June 26, 1978. "Weed", who was ranked third at the time of his removal from T-Troop in April, will be introduced into NT-Troop as soon as the animals in this group reach criterion on the behavioral test they are working on.

As the groups are now constituted, T-Troop contains 26 animals. There are seven adult males (over age 6), eleven adult females (over age 4), two subadult females (age 3-4), three juvenile males and one juvenile female (over age 1) and two unsexed infants.

NT-Troop contains 32 animals: Seven adult males, nine adult females, three subadult males (age 4-6), one subadult female, five juvenile males, one juvenile female, and two male and four female infants.

I-Troop contains seven adult and two subadult males.

Six T-Troop adult males, all seven adult males and one subadult male in NT-Troop, and all nine of the males comprising I-Troop are being tested on the various behavioral tasks employed in the project.

(2) Social testing.

Each group of animals is housed in an outdoor compound 12.2 x 3.4 x 2.0 meters high. The compounds are connected to indoor quarters that are heated and air conditioned. Each indoor cage is 6.1 x 1.2 x 7.5 meters high; the runways connecting the compounds with the indoor cages are 1.3 meters wide and 1.3 meters high. Metal perches and water fonts are located in both the indoor and outdoor sections. Sections of metal fencing, placed lengthwise in the outdoor compounds, serve to provide partial separation of the animals and, in effect, to increase the living space of each group. An observation station, 1.5 x 1.6 meters in area and containing electrical power and plug in jacks for the keyboard system used in recording social data, is centrally located in each outdoor compound. Swinging doors provide passage between the indoor quarters and the runways and guillotine doors are located between the runways and the compounds.

Observations of social behavior (usually one hour per group five times a week, weather permitting) are scheduled in accordance with the laboratory tests being conducted with the animals. In recording social behavior, the observers use a keyboard-tape punch

system, entering the code of the animal exhibiting a behavior, the code for the behavior itself, and then the code for the animal toward which the behavior is directed for each event which occurs. The system automatically punches the time of occurrence of the behavior and a code symbol which identifies the keyboard on which the behavior was recorded. As many as four keyboards may be used with the system. Frequency, latency, durational information and response sequences may be obtained from the data tapes. Additional analyses provide response matrices for each animal with respect to every other animal in the group. The behaviors that are currently being scored with the Java monkey group are given in Table 1.

Social rank is defined by defeats. The occurrence in any animal of a submissive behavior indicates that that animal is inferior in rank to the animal toward which the submissive signal is directed. The means by which one animal establishes and maintains dominance over another (e.g. by attack, threat, teaming up with another animal) may vary from animal to animal, from group to group, and from situation to situation. By recording and analyzing the social behavior of our animals, we define both the behavioral constancies and the range of variation seen in each of our subjects. This gives us a more sophisticated measure of social status and social organization than a simple assignment of rank. With such measures, the probability of detecting additional correlations between social behavior and performance on laboratory tasks is enhanced and the attempts to perform the essential causal analyses of these relationships will be greatly facilitated.

In the analyses of social behavior we are now using, each day's tape is initially analyzed by a PDP-8 computer which gives:

(a) A listing of the number of behaviors recorded for each animal for that observation period and a listing of the total frequency of occurrence of each behavior.
(b) A listing of the frequency with which each animal exhibited each behavior during the observation period.
(c) A listing of the frequency with which each behavior exhibited by a given animal was directed toward each of the other animals in the troop.

These listings are used to monitor day-to-day interactions in each group and to pinpoint changes in the relationships between individuals. A typical strategy is then to summarize the group relationships occurring before and after a major change in group structure by combining several days' data in a matrix analysis. In this procedure, the computer goes through all of the data and determines the social rank of each animal on the basis of who is defeated by whom, using the submissive behavior categories shown in Table 1. It then prints a series of seven matrices, using this rank order, in which the frequency of occurrence of each class of behavior we are interested in is given for each animal with respect to every other animal in the group. (At present we are limited to a 26 x 26 matrix, and infant behavior is not included). Four of these matrices are combinations of the behaviors listed under the functional

categories Aggressive, Submissive, Sexual, and Other Social that are given in Table 1. For the other three matrices, we select any three individual behaviors that may be of interest to us - for example, we might select Lip Smack, Groom, and Sit Next To as behaviors for these three matrices.

An example of the matrices derived from the social data is given in Table 2. To conserve space, only the males that were undergoing laboratory testing are listed, and only the matrices for submission and aggression are shown. (Table 2 was given in the 1977 Annual Report. It is repeated here to clarify the procedures used.)

The top pair of matrices (A.) in Table 2, show the T-Troop males during the fall of 1975. The group is very stable, and there is very little aggression among the six males. There are no agonistic reactions between the alpha male, Capone ("B") and Madison ("C"), the second ranked animal. However, reference to the data from preceding months shows that Capone's dominance over Madison was established in April, 1975, was unsuccessfully challenged in May, and that Madison had submitted to Capone in every agonistic encounter they had during and after June. Some instability in the relationships between the three subadult males, Oliver ("D"), Cracker ("F") and Spiro ("E") is evident from the matrices.

On November 1, 1975, Weed ("U") an adult male was introduced into T-Troop. The second set of matrices, (B.) in Table 2, summarizes the males' behavior for 12 observation periods subsequent to the introduction. There was a marked increase in agonistic interactions among all of the males as Weed moved to second rank beneath Capone. Note that the relationships between Capone and Weed and Madison and Weed are not fully resolved and that the relationship between Madison and Gus ("A") has become ambiguous.

The final set of matrices, (C.) in Table 2, combines the data from the 11 observation periods we were able to record for December, 1975 and early January, 1976. (Another adult male was introduced into the troop on January 19, 1976). The amount of aggression has dropped substantially, Weed has established himself as the alpha male, the relationships among the three males have stabilized and hierarchy is linear.

(3) Additional analyses of social behavior and organization.

During the first two years of work with T- and NT-Troops, we concentrated on male social rank and on male response frequencies within the agonistic behavior categories in our search for relationships between social variables and performance measures. It has been obvious that the male social hierarchy as determined by the nature and direction of agonistic behaviors is a key factor in the social organization of our groups and plays an important role in directing the expression of both agonistic and nonagonistic behaviors among all members of the group. However, knowledge of the hierarchy and of the associated agonistic behaviors is not sufficient for a thorough understanding

TABLE 1

Java Monkey Behavior Categories

__Agonistic Behaviors__:

- __Aggressive__
  - Chase
  - Threat (open-mouth)
  - Charge
  - Slaps
  - Bites
- __Submissive__
  - Avoid
  - Grimace
  - Squeal
  - Flee
- __Other Agonistic__ *
  - Lid
  - Lip Smack
  - Enlist

__Sexual Behaviors__:

- Sexual Present
- Mount (no thrusting)
- Mount (with thrusting)
- Masturbate
- Genital Manipulation (other animal)
- Genital Sniff

__Other Social Behaviors__:

- Present to Groom
- Groom
- Ventral-Ventral Hug
- Ventral-Dorsal Hug
- Sit Next To (physical contact with other animal)
- Play *

__Non-Social Behaviors__:

- Self Groom
- Move
- Sit - No Social

* "Lid", a flash of the white eyelids, "Lip Smack", and "Enlist" are scored, but are not currently used in the analyses described in the text. Lid is a part of the "pout threat" (Angst, 1975) commonly used by subordinate animals, lip smack is ambiguous and perhaps should not even be classed as agonistic, while enlisting occurs very infrequently in our groups. "Play" occurs only in infant and juvenile animals and is difficult to define reliably.

TABLE 2

Aggressive and Submissive Behavior Matrices for T-Troop Males Before, During, and After Introduction of Weed*

(A.) OCT '75 (12 Days)

RANK	ANIMAL	CODE	SUBMISSION: B	C	A	D	F	E	Total	AGGRESSION:	B	C	A	D	F	E	Total
1	Capone	B	–	0	0	0	0	0	0	B	–	0	0	0	3	0	9
2	Madison	C	0	–	0	0	0	0	0	C	0	–	0	0	1	1	7
3	Gus	A	3	3	–	0	0	0	6	A	0	0	–	3	1	0	10
4	Oliver	D	2	4	10	–	0	1	17	D	0	0	0	–	0	6	16
6	Cracker	F	5	4	6	0	–	1	17	F	0	0	0	1	–	1	5
8	Spiro	E	3	2	1	9	2	–	20	E	0	0	0	0	0	–	1

(B.) NOV '75 (12 Days) Weed Introduced

RANK	ANIMAL	CODE	SUBMISSION: B	U	C	A	F	D	E	Total	AGGRESSION:	B	U	C	A	F	D	E	Total
1	Capone	B	–	2	0	0	0	0	0	2	B	–	14	1	4	1	4	0	50
2	Weed	U	27	–	11	0	0	0	0	39	U	0	–	5	0	2	3	2	20
3	Madison	C	4	12	–	2	0	0	1	19	C	0	12	–	1	1	4	4	23
4	Gus	A	5	9	5	–	0	0	0	19	A	0	1	2	–	4	8	8	33
6	Cracker	F	8	10	5	13	–	0	0	37	F	0	1	0	0	–	1	4	13
9	Oliver	D	5	8	7	18	0	–	0	40	D	1	21	0	0	1	–	4	38
10	Spiro	E	1	3	6	14	2	5	–	35	E	0	0	2	0	0	0	–	7

(C.) DEC '75 - JAN '76 (11 Days)

RANK	ANIMAL	CODE	SUBMISSION: U	B	C	A	D	F	E	Total	AGGRESSION:	U	B	C	A	D	F	E	Total
1	Weed	U	–	0	0	0	0	0	0	0	U	–	0	1	1	0	0	0	4
2	Capone	B	5	–	0	0	0	0	0	6	B	0	–	0	4	0	3	0	11
3	Madison	C	10	0	–	0	0	0	0	10	C	0	0	–	4	0	0	0	12
4	Gus	A	10	15	7	–	0	0	0	33	A	0	0	1	–	0	3	5	31
5	Oliver	D	2	1	1	1	–	0	0	5	D	0	0	0	0	–	3	2	10
6	Cracker	F	2	0	1	8	6	–	0	18	F	0	0	0	0	0	–	2	4
7	Spiro	E	0	7	2	7	7	2	–	25	E	0	0	0	0	0	0	–	3

* Ranks are determined on the basis of defeats. Data are given only for males being tested on laboratory tasks. Where ranks of males are not consecutive, adult females hold the intervening positions. Reading the matrix horizontally indicates the number of times the animal "does" the behavior to each other animal. Reading vertically gives the number of times the animal "receives" the behavior from the other animals. For example, in the November matrix, Capone ("B") submits twice to Weed ("U") and aggresses against him 14 times; Weed submits to him 27 times and Capone receives only one aggressive response, by Oliver ("D") during this period. The total number of responses directed toward all animals in the troop by each male is given at the right of each matrix in the "total" column. Further details may be found in the text.

of the social behavior and organization in these groups. In the last annual report, we pointed out some of the differences in social behavior and organization between T- and NT-Troops. Since some of the relationships between performance on laboratory tasks and social variables which we have uncovered appear in both groups and some do not, there is the possibility that such differences are related to differences in the behavior and the organization of the groups. (Alternatively, of course, failure to confirm a relationship found in one group when the other is studied could mean that the relationship is spurious.)

Confirmation of the hypothesis that differences in social behavior and organization between groups can account for quantitative and qualitative differences in relationships between social and performance variables would be an exciting finding and an important first step in the causal analysis of these relationships. On the other hand, a failure to reject the null hypothesis in this case will lead us to concentrate on those social-performance relationships that cut across groups and will simplify our task by reducing the number of relationships to be analyzed.

The recent literature has provided a good background on the social behavior and organization in Java monkeys in both wild and captive groups (Angst, 1975, deWaal, et al., 1976) which we can use in assessing our own data. In addition, we have begun using a technique first applied to primate social studies by one of our former graduate assistants, in defining social organization in geladas (Theropithecus gelada) Fischer, 1977).

This technique, which is based upon a graph theory model proposed for systematic biology by Wirth, Estabrook & Rogers (1966), provides a cluster analysis from which clustering coefficients ("C" values) are derived which permit one to make probability statements about the strength of the relationships between individuals. In conducting such an analysis, the frequency data for the behavior under investigation is used to construct a matrix giving the number of times each animal does that behavior to every other animal in the group and receives that behavior from every other animal in the group. The cell frequencies are then transformed to proportions, using the row and column marginal totals, and normalized with an arc sine transformation. Z scores are calculated for the transformed cell frequencies and associated with probability estimates. Using the Wirth, et al. assumptions, the probability statements become the "C" values.

Dr. Fischer used this technique in his dissertation to show that, while both geladas and the hamadryas baboons (P. hamadryas) are organized into one-male reproductive units, the basis for the maintenace of these units is totally different. In hamadryas, it is based on male aggression; in geladas, affiliative behaviors are the key.

The past winter we began applying this technique to the data from our animal groups. The social data from T- and NT-Troop for the last nine months of 1977 were cumulated and analyzed for the broad functional categories of aggression, submission, sexual, and "other social"

behavior. The cluster analyses of nonagonistic, nonsexual social behavior (e.g. sitting with, hugging, grooming variables, etc.) produced some very interesting relationships. There was several subgroups within each troop. Nonagonistic nonsexual social behavior by females was directed primarily toward their mothers (if the mother was still in the troop). The mothers did not reciprocate, but directed their behavior of this type toward their eldest sons; who, in turn, did not reciprocate. Males, in general, showed less of this behavior; if a male was high ranking, his behavior was directed primarily toward females other than his mother. If he ranked intermediate or low, his nonagonistic, nonsexual social behavior was directed toward other low or intermediate ranking males. Additional social and agonistic analyses reveal the presence of alliances between males which are very important in relation to the rank a male is able to maintain. Finally, the sexual data indicate that a male does not copulate with its mother, but may do so with a sister if the mother is no longer in the group.

The data from which the above relationships emerged were obtained from observation periods during which the observers were attempting to scan the entire group throughout the time period. They tended to concentrate on agonistic behaviors and on the behavior of the males that were undergoing laboratory testing since these were the animals most crucial to the research program. To help confirm the accuracy of the analyses described above, observations using a "focal animal" technique are now being employed. Additional focal animal observations will be conducted throughout the coming year. With this technique, selected animals are watched continuously for a given period of time, and all behavior they give or receive from all animals in the troop are recorded. For example, we have recently used successive five minute samples of four adult males and four adult females in each observation period of NT-Troop. (The focal animal observations are done in conjunction with, not in place of, our regular observation procedures.)

We expect the results of these analyses to have important implications for the next stages of the research project. For example, we now manipulate the social situation in our groups by direct removal and replacement of the males that are undergoing laboratory testing. The additional information provided by the clustering techniques provides the basis for different kinds of experimental manipulations of the social mileau. We can determine how much and what kinds of support a particular animal receives from other members of the troop. Leaving this animal in the troop, but using a technique of removing or adding other animals, such as mothers, consorts, allies, etc., we will alter both affiliative and agonistic relationships and expect to obtain a much clearer picture of the relationship between social variables and performance variables. It will be no surprise if it turns out that if an animal's social rank is based on its own successful agonistic encounters its laboratory performance may be somewhat different than if its rank is based largely on its alliances or upon matriarchical support, etc.

A second advantage is that the more sophisticated analyses of social behavior and organization offers a means of clarifying dominance relationships among animals. As indicated earlier, our operational definition of social status depends on agonistic interactions - an animal's rank depends upon which other animals it loses to. Once the status relationship between two animals has been resolved, there may be little agonistic interaction between them for an extended period of time. The problem is acute for determining the precise status relationships among lower ranking animals because inaccurate determinations can seriously affect the correlations between rank and performance measures. The data indicate that, in general, nonagonistic, nonsexual social behavior is most frequently directed to the dominant member of any male dyad by the subordinate member of the pair. Much less (sometimes virtually none) is directed back to the subordinate animal by the dominant male. Similarly, we have hypothesized that social/performance relationships are most apparent in animals that are most actively engaged in the social dynamics of the group. The clustering procedure allows us to test this quite directly and hopefully will enable us to determine the nature of the factors that are important in determining social/performance relationships.

Finally, we plan to determine social "profiles" for each animal. These profiles will be clustered to see if we can classify our experimental animals into "Types" which will then try to relate to dimensions of laboratory performance (see parts E and F of this section).

B. Open Field Tests:

A variety of tests have and are being conducted in an open field arena to determine whether or not there are relationships between social variables and measures frequently associated with emotionality, responses to unfamiliar environments, locomotor activity, reactions to novel stimuli, and the like.

Testing is conducted in a square open field, 3.66 M on a side and 1.83 M high which has been constructed in a large room indoors in the laboratory building. The walls, constructed of asbestos cement board, and the concrete floor are painted white. The floor is divided into 16 equal squares by a painted grid; five threaded studs, one in the center and the other four arranged in a square pattern equidistant from the center stud and the arena walls, are embedded in the floor. These are used to attach novel objects used in some of the studies. The arena is covered with 2 in. chain link fencing and is illuminated by four 150 watt floodlights placed above the chain link ceiling. There are two guillotine doors located at diagonally opposite corners of the arena; these doors exactly fit the dimensions of the doors of our animal transport cages. A larger door is located along one wall and allows people to enter the field to place objects in the field and for cleanup. An elevated platform is located along the outside of one wall which enables the observers to look down into the arena. An opaque curtain on either side of a large one way mirror prevents the animals from seeing the observers. Also located at

the observer's station are the ropes controlling the guillotine doors and a keyboard which is connected to the laboratory computer located across the hall. Punching the appropriate keys on the keyboard for the different behaviors exhibited by the animals causes the data to be stored in the computer; at the end of a test, the data can be punched out on paper tape and/or stored on floppy disc for later analysis.

Tests are run for either three or five consecutive days on the problems we have devised for use within the open field; the number of days depending upon the nature of the problem, the configuration of the open field, and the amount of time necessary for performance to stabilize. The basic procedure is to bring each animal to the apparatus in a transport cage, open the guillotine door, and allow the animal a maximum of 15 minutes to emerge into the open field. "Emergence" requires the animal to enter the arena and move beyond the first square of the field (a distance of @.92 meters). When the animal has emerged, the guillotine door is closed behind him and the behavior of the animal during the ensuing five minutes is recorded. At the end of five minutes, the guillotine door is reopened and the animal's latency in returning to the transport cage is recorded as are the behaviors that occur during this latency period. In the test situation with an empty arena, then, the behaviors that are recorded are:

(1) Head Out Latency: Time from opening the guillotine door until the animal pokes his head through the door of the transport cage into the arena. (max. 900 sec.)
(2) Body Out Latency: Time from opening of guillotine door until the animal enters the square of the arena directly in front of the guillotine door. (max. 900 sec.)
(3) Number of Returns: Number of times animal reenters transport cage after entering first square ("body out").
(4) Emergence Latency: Time from opening of guillotine door until animal "emerges" (as defined above).
(5) Exploratory Moves: Number of squares traversed during the five minutes following emergence until the guillotine door is reopened.
(6) Return Latency: Time from the reopening of the guillotine door until the animal reenters the transport cage.
(7) Return Moves: Number of squares traversed during the return latency period.

The time spent on the floor as differentiated from that spent hanging from and moving about on the ceiling is also recorded.

With novel objects present, the frequencies of the following additional behaviors are also recorded:

(8) Lip Smack
(9) Orientations to object(s)
(10) Manipulations of object(s)
(11) Threats to object(s)
(12) Bites (object)
(13) Other contacts with object(s)
(14) Vocalizations
(15) Self Directed Behaviors (groom, masturbate, etc.)

Tests using the bare open field were conducted during the last three months of the 1976-77 contract year using all of the animals from both T- and NT-Troops that were undergoing the other behavioral tests. Tests were conducted for five consecutive days. There was a rank order correlation of +.81 between high social rank and the number of squares traversed during the five min free exploration periods for the nine males from T- Troop ($t = 3.38$, $p = .015$). Median emergence latency was not related to rank when all nine animals were included in the analysis; however, if only the top six ranked males (those that presumably were the ones most actively involved in the maintenance of the male dominance structure of the group) were considered, the correlation between high rank and short emergence latency was +.97. In NT-Troop, the relationship between high rank and squares traversed appeared only among the five oldest and highest ranking males. There was no relationship between emergence latency and social rank in this group.

In January, 1978, the males were retested in the bare open field using the same procedure employed a year earlier and with the test conducted for three consecutive days. Animals tended to show levels of exploration similar to those of the preceding year, but it was obvious that some adaptation had occurred. The biggest problem was the refusal of Capone, Madison and Oliver, from T-Troop and of Eju, from NT-Troop, to enter the open field on this series of tests. Needless to say, there was no correlation between open field measures and social rank.

In February, 1978, the animals were tested again, this time with a stuffed teddy bear @ .33 M long by .25 M high placed in the center of the field. The stuffed toy was mounted on a wheeled platform that was pivoted on the stud in the center of the floor so that the toy would spin when touched with any force. There was a reliable increase in emergence latency for the T-Troop males; however, once again, Capone, Madison, and Oliver refused to enter the field. In the six animals that did enter the field, there was a near perfect correlation between high rank and high locomotor exploration. In NT-Troop, emergence latencies tended to be longer in the five oldest and highest ranking animals - the exception here was Eju who emerged on all three trials with the novel object in the field after failing to do so in the bare field. Eju, ranked third, did relatively little exploring (although he attacked and bit the stuffed toy more than any other animal) and the two top ranked animals, Knees and Ian did the most exploring, followed by Alabama, ranked 4th, and Barker, ranked fifth ($rho = .82$, $p = .09$, two tailed).

There were no consistent relationships between social rank and behavior toward the novel object. In T-Troop, contacts between the animals and the object were relatively few and those that were made bore no particular relationship to social status; the lower ranking animals tended to show more orienting behavior. In NT-Troop, the higher ranking animals tended to contact the object more than the other animals, but the relationship was not very strong. Overall, the frequency of animal/object interactions was much higher in NT- than in T-Troop.

We are now conducting the third experiment in this series. This consists of exposing the animals to four objects and then studying their

reaction when one of the objects is replaced by a novel object. In order to do this properly, we are now training all of the animals to be tested to enter the open field for food reward, so that we will not have the problem of having animals refuse to go into the arena. At the present time, only Eju, from NT-Troop, has not completed training.

One more task is scheduled for the coming contract year. As will be seen in the next sections, our studies of complex problem solving in the WGTA test situations, are revealing some interesting relationships between problem solving and social behavior. To test for the generality of these relationships, we will run our animals on the Hebb-Williams maze learning problems using the open field and moveable barriers to set up the problems. Transport cages at diagonally opposite corners of the arena will serve as start and goal boxes in this series of 12 maze problems.

C. Complex Problem Solving:

In testing 15 male Java monkeys on a visual discrimination reversal task, we found that high ranking animals tended to do more poorly in learning a series of successive reversals than low ranking animals (Bunnell, Gore, Norris, and Steere, 1977). Meyer (1971) found that monkeys relearn a reversal task after performance on that task has been extinguished in about the same number of trials and in approximately the same way they first learn the problem. In order to see if reversal performance would vary as a function of experimental manipulations of the social structure and organization of our groups, we are conducting a series of reversal learning/extinction tasks using object quality learning set problems and the WGTA apparatus.

The animals are trained and tested in a modified WGTA which is fitted with a gray stimulus tray containing two food wells (4 cm in diameter, 1.25 cm deep, 15 cm apart, and 6 cm from the front edge of the tray). The discriminanda are small plastic, metal, or wooden objects of different colors, shapes and sizes purchased from a toy store and a supermarket. The monkeys are placed in an individual cage (60 x 60 x 70 cm) located in a windowless room which is flooded with 65 db of white noise to help minimize distractions. The WGTA is wheeled up to the cage for testing. The WGTA is so constructed that when the door is raised, the stimulus tray is available though a space at the bottom of the cage (5 x 33 cm). A plexiglass window (13 x 33 cm) is located just above this space and allows the animal to see the stimulus array without being able to reach it except through the lower opening.

Raisins are used for reinforcers, intertrial intervals are 30 sec and response intervals, 20 sec. A 50-W frosted incandescent bulb, placed at the top center of the WGTA provides the only illumination during testing.

The animals are first trained to criterion on a six-trial object quality learning set task and are then given a short series of 10-trial problems. Criterion on both tasks is 17 out of 20 correct responses on trial 2 for 20 consecutive problems. They are then given the reversal task. In this condition the animals are given four problems per test session with lengths of 8, 9, 10, and 11 trials (the order or problem

lengths is counterbalanced). Reversals occur on the fifth trial of the 8-trial problems, the sixth trial of the 9-trial problems, etc. and continue through to the end of that problem. Criterion is 17 out of 20 correct responses on the trial following reversal on 20 consecutive problems. Finally, reversal extinction is introduced. This is similar to the reversal condition except that the correct stimulus is reversed for only one trial after which the original positive stimulus is reinforced for the remainder of the trials on the problem (Problem lengths under this condition are 9, 10, 11, and 12 trials.) Criterion is 17 out of 20 correct responses on the trial following the reversal trial on 20 consecutive problems.

Nine males from T-Troop (including three that are now in I-Troop) have completed the reversal extinction procedure. The higher ranking animals made more errors on the first 30 problems of the 6-trial learning set task than lower ranking animals (the rho between errors and rank was +.65, $t = 2.26$, $df = 7$, $p = .06$, two-tailed). This trend had disappeared by the 330-360th problems, although the higher ranking animals were still making more errors. Seven animals from NT-Troop (including two that are now members of I-Troop) have completed training on both the 6-trial and 10-trial object quality learning set problems. Although there was a slight trend for higher ranking animals to do more poorly on the 6-trial problems, it was not as pronounced as in T-Troop. However, when given the 10-trial problems, the trend became much more pronounced (rho = +.65) in the NT animals. (The T-Troop animals transferred their learning to the 10-trial problems with very few errors and there was no relationship between rank and performance in this group on the 10-trial task.)

In the nine T-Troop animals the correlation between problems to criterion on reversal learning and rank is +.71; in the seven NT-Troop animals it will be at least +.86 on the reversal task (the first and third ranked animals are still running and have already exceeded the number of problems given to the other 5 animals that have reached criterion). Under the extinction condition, the correlation between problems to criterion and rank is +.73 in T-Troop; the data are incomplete but it is likely that there will also be a significant relationship in NT-Troop on the extinction condition.

Thus, the early data from the visual discrimination reversal learning experiment have been confirmed and extended in the present study. There are two findings of interest in addition to the verification of the previous work. The first is the tendency of the higher ranking animals to perform more poorly during acquisition of an object quality learning set. A question of importance is the number of dimensions on performance that may be operating here. We have factor analyzed the old visual discrimination reversal learning data and come up with two factors, one which seems to be related to overall performance (learning ability? ease of adaptation of the WGTA testing situation?) and one that appears to be more specifically related to strategies used in the reversal learning task per se (flexibility? inhibition?). It will be very interesting to see if the object quality/reversal learning data reveal some similar patterns. Putting the analyses from the two tasks together should give us some insight into the dimensions we are dealing with and should help us

determine which dimensions are important for the social/performance relationships we are investigating. The second interesting result is that there is an indication that animals that have risen in rank since they were tested on the visual discrimination reversal task are tending to show poorer performance when tested on the object quality/reversal learning task - it may well be that our hope of finding a complex task that is sensitive to changes in the social situation and can be used repeatedly is going to be fulfilled. We'll know better in the next few weeks as we retrain the animals in the reorganized T-Troop. Finally, data from another study of complex problems solving using some of these same animals are available (Czerny and Bunnell, 1977) and will be analyzed to see if we can identify performance dimensions that are similar to those of either or both of the reversal and learning set tasks.

D. Operant Conditioning:

Meier and his coworkers (e.g. Bartlett and Meier, 1971) have looked at operant behavior in a communal group of rhesus macaques. Using Fixed-Ratio (Fr) schedules for monkey chow (FR-32 for 22 hours a day) and fresh fruit (FR-16 for 2 hours a day) as incentives, they found that rate of bar pressing was significantly correlated with dominance status. The higher ranking animals responded at a slower rate. Individual differences in rate or intensity of response did not vary as a function of social context, suggesting that the differences might be quite stable, perhaps as a function of a history of differential learning of dominance related behaviors. (Dominant animals had priority at the manipulandum; they pressed at low rates, and paused to eat the food after it had been delivered. Subordinate animals would not respond in the presence of higher ranking animals; they pressed at high rates and would often resume pressing while eating a recently delivered piece of fruit).

The first reliable relationship between social variables and performance that we found was the result of studies using rhesus monkeys that were tested on a Fixed Interval - 1 minute schedule (FI-1 min.). When reinforcements were omitted, randomly, after 20% of the intervals, the ratio of nonreinforced to reinforced responses was higher in high ranking animals than in low ranking animals (Bunnell, Kenshalo, Allen, Manning & Sodetz, 1979; Bunnell, Kenshalo, Czerny, & Allen, 1979).

(1) Operant testing background of current subjects:

When, in December of 1974, it became necessary to switch from rhesus to Java monkeys for the majority of the work on this project we repeated the use of the FI 1-min schedule with omission of reinforcement with the new species. A total of nine animals in T-Troop were tested beginning in the winter of 1975 and continuing through the winter of 1976. During this time, three of the animals were introduced into the troop at various intervals in order to manipulate the social situation. Twelve NT-Troop males were tested on the same task beginning in the Spring of 1976 and continuing until Spring, 1977. During this time, several removals of key animals, followed by their later reintroduction into the troop, were made in order to manipulate their social situation. These same NT-Troop males had

been trained and tested on a differential reinforcement of low rate (DRL) schedule with a limited hold (LH) contingency added to it. (In the DRL 18-sec LH 5-sec schedule we have used, a response made within a 5 second window beginning 18 seconds after the preceding response results in reinforcement. Shorter or longer interresponse times (IRTs) are not reinforced and merely reset the DRL requirement.) DRL testing which included concurrent manipulations of the social group took place from the spring of 1975 through the winter of 1976. The nine T-troop males were tested in similar fashion in 1976-1977. Details of those procedures may be found in our last annual report.

The ratios of nonreinforced to reinforced responses (omission ratios, or ORs as they are termed here) on the FI 1-min schedule have been said by some (e.g. Amsel) to be a measure of frustration following nonreward. Others (see Staddon, 1970, 1971) believe that the response bursting which typically follows nonreinforcement under this paradigm is not due to an increase in excitation following nonreward but is explained by an inhibitory effect of reinforcement so that nonreinforcement leads to enhanced responding.

Typical performance on a DRL schedule results in a modal inter-response time which just exceeds the criterion value,t. However, a significant portion of the total responses in a session consists of series of short IRTs (response bursts) which often occur following the emission of a nonreinforced response and are detected as a smaller, second, mode in the IRT distribution. It has been argued that these bursts are the manifestation of frustration resulting from the emission of a nonreinforced response which extends the temporal requirement to the next available reinforcement. For instance, DRL schedules are preferred less than VI schedules having equal reinforcement frequency when programmed on a concurrent schedule (Rachlin, 1973), and produce positive behavioral contrast in the VI component of a multiple VI DRL schedule (Bloomfeld, 1967). High "frustration" on the DRL schedule would be manifested by a correspondingly high response to reinforcement ratio. In addition, a relatively independent measure of timing efficiency is provided by calculating the median and variance of the IRT distribution from which the response bursts in the first bin have been deleted. An efficiency ratio, the ratio of total number of responses to the number of reinforced responses can also be used.

The findings from the studies using these two operant schedules in combination with experimental manipulations of the social groups in which the animals lived appear to be clear in the case of the performance of the DRL task, but equivocal with respect to performance on the FI 1-min schedule.

On the DRL, a high rate of response bursting was associated with high frequencies of aggressive behaviors in the social situation. This relationship appeared in both adult and subadult males in T-Troop but only for the five males of NT-Troop who were adults when they were tested. A second finding was that good performance on the DRL

(a low efficiency ratio) was associated with high rank for both the 5 adults of NT- and the 6 adults of T-Troop that were tested.*

The relationship between high ORs and high social rank that we found in rhesus monkeys has not been as apparent in Java monkeys tested on the FI schedule. Although the expected trend was there (more so in T-Troop than in NT-Troop animals, incidentally) the correlations between rank, frequency of aggressive behavior, or frequency of submissive behavior on the one hand and ORs on the other were nonsignificant. When, however, we looked at the correlations between rates of responding after reinforced intervals with rates after nonreinforced intervals, we found that the expected correlations between ORs and rank did appear in animals whose reinforced/nonreinforced response rate correlations were high and positive, but not when the correlation was insignificant, or large negative. This suggests that the animals may have at least three ways of dealing with the schedule contingencies, or that perhaps multiple factors contribute to the OR (activation? reinforcement inhibition effects? + something else?).

Our first attempt to understand what may be going on has been to use a new paradigm in which we have attempted to get all animals onto a high, stable rate of baseline responding before omitting reinforcement and have invented a manipulandum which seems to have, at least for us, a higher face validity in the production of "frustration" in our subjects.

(2) <u>The</u> "<u>VI</u> - <u>Frustration</u>" <u>test</u>:

Following completion of operant testing on either the DRL 18-sec or the FI 1-min schedule with omission of reinforcement, all 21 males from our two social groups were switched over to a VI 1-min schedule using a new manipulandum. This consists of a hopper with a plexiglass door that is latched until the schedule requirements have been met. A banana pellet is always present behind the door, and the animals' presses against the door are scored. When the animals have stabilized their performance on the VI 1-min schedule, a condition is introduced whereby reinforcement is omitted on certain trials. This is done by dropping the pellet through the bottom of the hopper just as the schedule requirements have been met. Because the animals were coming off two different schedules they were first given 4 days of training on an FI 10-sec schedule; on April 1, 1977, they began training on a VI 30-sec schedule and on April 18 they started on the VI 1-min schedule. In late June, the reinforcement omission condition was introduced to the 9 animals from "T-Troop"; the 12 animals from "NT-Troop" started testing under this condition in early July, 1977.

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* It should be noted that young animals, as a group, consistently outperform the older males on the DRL, just as they do on the FI the 60-sec and on the WGTA tasks we have run to date. The best DRL performance of the older males has, with one exception, been worse than that of the subadult males.

Testing on this task was completed for both troops in late December, 1977. During the course of the entire study, three adult males were removed and replaced in each group in order to study the effects of social manipulation on the operant performance.

One finding from this study was that we were able to demonstrate response enchancement in 13 out of the 20 animals that completed testing (one animal was dropped because of intermittent illness during the fall) in a situation where response patterns were unaffected by temporal control artifacts (Adams, Allen, & Bunnell, 1977). When the operant data were correlated with social variables, it was found that there was a significant correlation between rank and local rate ratio during the two weeks prior to the removal of the alpha male in T-Troop (rho = .70, t = 2.59, df = 7, p = .04). (The local rate ratio is defined as the ratio of rate of responding in the first 12 sec bin following nonreinforcement over the rate of responding in the first 12 sec bin following intervals that were reinforced.) Removal and replacement of the alpha male produced a correlation of +.66 between high rank and high omission ratio and of +.90 between high rank and high local rate ratio. By the end of the study and the completion of the social manipulations, the correlation between rank and local rate ratio was still a respectable +.68. However, in NT-Troop there was no relationship between rank and performance throughout the course of study. One possible explanation of the discrepancy between the T- and NT-Troop data lies in the differences in the social behavior observed in the two troops. In T-Troop, there was a fair amount of agonistic activity throughout the study and the removal and replacement of different males produced increases in agonistic behavior and some definite changes in rank. In NT-Troop, however, the group was relatively inactive, there was little aggression, and the social manipulations did not produce either a marked increase in aggression or any profound alteration of the rank structure. It may be, then, that the manifestation of social/performance relationships will occur only when active tensions exist within a group and the social structure is under pressure.

To follow up the results of the first study, the animals in I-Troop have been kept working on the VI 1-min schedule throughout the period of their removal and isolation from their original groups, the formation of the original 7-member I-Troop, and the subsequent introduction of the remaining two members. A summary of the omission ratio data for this study to date is given in Table 3. The overall correlation between the mean omission ratio of each animal since it has been in the troop and its present rank is +.74 (t = 2.91, df 7, p = .02, two-tailed). If the two subadults are excluded (they appear to be in the group but not really of it, at present) the correlation is +.83. The local rate ratio data are similar, but more variable; (there is, however, a .94 correlation between local rate ratio and rank during the two weeks following Alabama's introduction). The nature and direction of some of the changes in the performance of individual animals are, quite interesting and are to be analyzed further in terms of amount and kind of social behavior exhibited during the different stages of the study. Unfortunately, a breakdown in the

TABLE 3

I-Troop Omission Ratios,
VI 1-Min Schedule, May-June 1978

Animal	Animals Isolated May 1-15 Rank	OR	Group Formed May 16-22 Rank	OR	Alabama In May 31-June 12 Rank	OR	Cracker In June 14-23 Rank	OR	$\overline{X}$ OR while in group
ALABAMA	-	1.18	-	(1.35)	1	1.49	1	1.17	1.33
GUS	[illegible]	.95	T-1	1.06	2	1.36	2	1.11	1.18
SPIRO	[illegible]	[illegible]1	T-1	1.05	3	1.08	3	1.23	1.12
EQUAL	-	[illegible]5	6	1.32	4	1.33	4	.89	1.18
CRACKER	-	1.02	-	(.99)	-	(.66)	5	1.02	1.02
DAQUE	-	.91	7	1.05	5	.62	6	1.19	.95
*NOD	-	1.00	T-4	1.03	T-6	.83	T-7	.99	.95
*YAMAMOTO	-	.99	T-4	1.06	T-6	1.09	T-7	.94	1.03
YUK	-	.69	3	1.13	8	.97	9	1.07	1.06

* Subadults and allies

keyboard/punch system occurred during this time and two weeks of data have had to be recorded by hand to be transcribed to paper tape after the system had been fixed. We have not yet gotten a complete analysis of all of the social data for this study. These animals are scheduled for retraining and extinction on the reversal learning problem in July, so the effects of further social manipulations on VI performance will have to wait until this WGTA testing is done.

(3) Changeover ratio schedule:

The one performance task we have looked at in which high ranking animals have consistently out-performed lower ranking animals has been the DRL schedule. Here the higher ranking animals achieved better efficiency ratios more quickly than lower ranking animals during acquisition. To pursue this further, the T- and NT- males are now being trained and tested on a changeover ratio schedule. The rationale for this is that the ability to "count" accurately would be a meaningful component of efficient behavior and would perhaps be particularly relevant to a social animal whose well-being depends upon the accuracy of discriminating his position within the group hierarchy. The changeover ratio provides a measure of counting accuracy.

The animals are trained to press a bar 12 times after which a changeover to a second response, in this case a door press on the hopper manipulandum, produces a pellet. Responses on the changeover manipulandum which follow an incorrect sequency length are not reinforced, but reset the 12 response requirement on the bar. At present, only sequences that are too short reset the requirement - we have not as yet imposed an upper limit, but may do so in the future. The animals are allowed to obtain 40 food pellets per day on this schedule.

The data are recorded in sixty response bins (0-59) according to the number of bar presses the animal makes prior to pressing the door of the hopper. (Bin #59 is an overflow counter.) From this, the median number of bar presses the animal makes before it makes a door press is calculated as is the interquartile range and the total number of response sequences initiated by the animal (a sequence is scored anytime the animal makes one or more bar presses before it presses the door). The "0" bin records successive presses on the door without intervening bar presses and is a measure we think may be akin to response bursting under the VI schedule.

Training on this schedule was begun in January, 1978 with the 14 males from T- and NT-Troops that had been on the VI 1-min schedule and which had not been selected for I-Troop. In April, Knees was removed from NT-Troop and Weed from T-Troop. These two animals continued their training, but have been kept in individual cages in the laboratory. Training on this schedule has been rather slow, expecially in NT-Troop, due to the animals' apparent difficulty in shifting over from the VI schedule. As the end of June approached, however, T-Troop performance had stabilized quite well and Knees will be introduced on June 27. Weed is to be introduced to NT when

TABLE 4

Performance on Changeover Ratio of 12 : 1
June 14-23, 1978

T-TROOP:

Animal	Rank	Median Presses/ Sequence	Inter-quartile Range	"0" Bin Responses (Proportion)
EASY	1	12.26	2.84	.15
CAPONE	2	10.06	6.49	.34
MADISON	3	9.51	7.58	.39
OLIVER	4	.86	7.14	.59
LEGS	5	.77	5.77	.60

NT-TROOP:

Animal	Rank	Median Presses/ Sequence	Inter-quartile Range	"0" Bin Responses (Proportion)
IAN	1	13.68	5.37	.23
EJU	2	13.74	2.46	.10
BARKER	3	18.70	3.62	.06
TAG	4	.89	.65	.56
ARISTOTLE	5	10.52	7.59	.44
*QUOTATION	6	.91	4.00	.56
**HOBBIT	7	9.17	6.53	.38

* Working under a ratio of 8:1

** Subadult

performance in that group improves a bit more; this introduction will probably take place during the second week of July.

During the first few months of training on this schedule, there was no apparent relationship between performance and the social variables. However, as the end of training approaches, it appears that the higher ranking animals are doing somewhat better than the lower ranking animals. Table 4 summarizes the data for the two weeks in June, 1978, just prior to Knees' introduction into T-Troop. Easy, the alpha animal in T-Troop, is performing very well. His median bar presses per response sequence of 12.26 is very close to the schedule requirement of 12, there is little variation around the median (2.84) and he wastes relatively little effort on repeated presses of the hopper door. The overall trends between rank and performance are quite apparent from the table. Even though Oliver, Legs, and Tag are wasting a lot of effort, they are usually managing to complete each session and collect their 40 food pellets. Quotation is interesting; he can count, but so far only up to eight. If the schedule requirement is raised to nine he presses the bar eight times, presses the door and when it won't open goes and sits in a corner for the rest of the session. Hobbit is a subadult and performs fairly well.

Once the introduction of Knees and Weed are completed and the social behavior stabilizes, all of these animals will be retrained on the reversal learning/extinction task. They will be kept on the changeover schedule during this time after which another social manipulation will be made. Depending upon the results at that time, we may modify the schedule requirements to include an upper limit on the number of responses in the sequence (to see if we can really get them to "count" to 12), omission of reinforcement on a random basis to see what the response bursting may look like, or a combination of both.

Conclusions and Recommendations

The work of the laboratory is providing a set of relationships between social behavior and organization on the one hand and individual differences in performance on a variety of laboratory learning and performance tasks on the other. The relationships which have emerged suggest that: (1) there are individual differences in performance on laboratory tasks which are related to the ease with which a given animal can establish and maintain high social rank and (2) that performance on certain laboratory tasks is affected by day-to-day and week-to-week changes in, and pressures of, the social situation.

We may find it useful to use other tasks in order to test hypothesis about the obtained social/performance relationships. One such task will utilize a comparison of performance on a multiple VI EXT schedule. There is a response enchancement - "behavioral contrast" - effect which is quite reliable but which exhibits considerable individual differences from animal to animal. We would like to see if, as we expect, the interindividual variance can be predicted by reference to each animal's social behavior

and status. We will use I-Troop on this task and would expect to begin testing about October 1, 1978.

During the most recent site visit to the project, one of the site visitors, Dr. Stephen Hirsch, suggested that we consider doing operant testing in the social situation. Dr. Hirsch's suggestion carried an additional refinement in comparison to the work of Meier and Bartlett we have mentioned earlier in this proposal; he suggested that each animal be given its own behavioral code by which it could set up an operant session for itself. We would like to try this as it offers some intriguing possibilities for directly relating performance and social variables. We have not been able to find out very much about such use of individual codes from the literature and we foresee some problems in implementing sucha procedure. Perhaps the best way of doing this will be to give each animal its own schedule and let it go at that. We know enough about performance on several schedules so that we can relate individual performance to our previous results. We will do some pilot work with this during the coming year and see what happens. We will begin by using one of two high ranking females in each group. The reasons for using females are two-fold. First, we can do the pilot work without interrupting our present testing schedule. Second, we have not been able to work with females very successfully in the laboratory so far. The high ranking animals tend to have infants every year and they don't like being tested if their infants are taken away from them during the test sessions. (It is sometimes a bit hard on the infants, also.) Leaving the infant on the mother, however, has created additional problems in the confines of the operant boxes. We may well be able to get much more satisfactory results if we try testing the females right in the social situation. It is certainly worthwhile giving this a try in view of the important role these females play in the social structure and organization of the group.

The major concern of the work during the coming year will be to try to extract performance dimensions from the various laboratory tasks that are being used. Hopefully using multiple regression techniques, we will be able to find sets of common elements which cut across the different performance measures we are using. Such dimensions will then be correlated with social variables to see which are related to social behavior and organization. Where correlations are found, they will provide the basis for the generation and testing of hypotheses about causal relationships between social behavior and performance. We have done some of these analyses on the old FI-60, the DRL, the visual discrimination learning set and the early open field data. Because we have a relatively large number of variables and a limited number of subjects we have had to factor analyze the individual tests first and then factor analyze the factors across tests. The results to date are equivocal; hopefully the addition of data from tests conducted during the last year will validate the use of this strategy. If not, we will fall back on the use of a profile analysis in which we will analyze across animals instead of tasks in the hope of extracting classifications, based upon the performance measures, that will be related to social variables. This too, would lead to the generation of hypotheses about the nature of social/performance relationships which will then be subjected to experimental test.

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